A Method for Evaluating Island Exploitation Degree Based on Multi-scale NDVI Analysis

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Abstract

In order to understand present status of island exploitation degree, and to make a reasonable development plan for future exploitation, this paper proposes multi-scale analysis evaluation model to achieve the goal. With the new proposed model and SPOT-5 image in 2003, the island exploitation degree of Daxie Island is evaluated. According to the comparison between in the same period land use classification and results of island exploitation degree, the proposed model is reasonable and valuable in dynamic evaluation of island exploitation degree.

Keywords

Remote Sensing; NDVI; Multi-scale; Island Exploitation Degree

Introduction

With the development of economy, urbanization is accelerated in everywhere of China. Along this trend, more and more nature woodland, grassland and farmland have been replaced by artificial buildings, such as factories, residential, bridges, etc. Urbanization has aggravated the tension of the land for construction, so it is necessary to figure out present land use condition and make reasonable land development plans for sustainable utilization of land resources. Many researchers have applied factor analysis with the selection of various indices from different points of view to land use evaluation. Wang (2001) chooses Land utilization ratio, forest coverage ratio, grassland utilization ratio, and other four indices to comprehensively evaluate the land exploitation degree of each county of western China, and divided them into several regions according to their values of exploitation degree. Zhang (2005) employed grassland utilization ratio, traffic utilization ratio, waters utilization ratio, and other four indices to evaluate land exploitation degree of Quzhou County, and then analyzed driving forces. Ke (2008) used four indices, including land use degree, comprehensive benefits of land use, overall level of land use, and intensive degree of land use, to evaluate present condition of land exploitation degree of Xianning city. Some other different indices have been used to evaluate land exploitation degree in different regions by Gao (2010), Cao (2011), and Zheng (2011). Although researchers have chosen different indices and methods to allocate weights of indices to evaluate different research regions, all of their methods are factor analysis essentially, and such method is skillfully applied in continental land exploitation degree. Islands surrounded by sea water make no differences to continental land without considering its natural geographical environment. Compared to continental land exploitation evaluation, island land exploitation evaluation gains less attention. Some researchers have applied the same factor analysis method to island resource sustainable utilization evaluation (Li 2003), island ecosystem health evaluation (Song 2006, Xiao 2007), and island land exploitation evaluation (Yao 2008). However, islands are different on geographical environment, economic development levels, and population size, etc., therefore conventional factor analysis method may fail to get expected results.

Besides, conventional factor analysis method needs all kinds of social and economical materials, which may be a limitation for wide application of the method, and the calculated results may lag behind present condition. Considering the shortcomings of factor analysis method, some researchers have done some analogous researches by using remote sensing technology. Fung (2011) and Ding (2011) used multi-temporal remote sensing images to monitor island vegetation change. Hill (1998) and Cheng (2010) evaluated island ecosystem health. Zhang (2003) used IKONOS images to monitor Naji Island land use. Wang (2008) used remote sensing technology and landscape analysis method to evaluate the risk of development of island. However, they all pay limited attention to the evaluation on island exploitation

degree. Thus, this paper proposes a new model to evaluate island exploitation degree based on NDVI from remote sensing technology.

Method

Conceptual model

In the process of exploitation of island, the nature environment, especially vegetation, is replaced by man-made buildings. Considering the characteristic of islands exploitation expanding from a single point to a large surface, the island exploitation model can be described as FIG.1(a). The central of model represents man-made buildings which has a high exploitation degree, and the outside of model represents nature environment, which has a lower exploitation degree. The profile (the red line in the FIG.1(a)) shows the exploitation degree of the points from left to right on the profile ranging from low to high, and then to low. This trend is plotted into a regular convex line (FIG.1(b)).

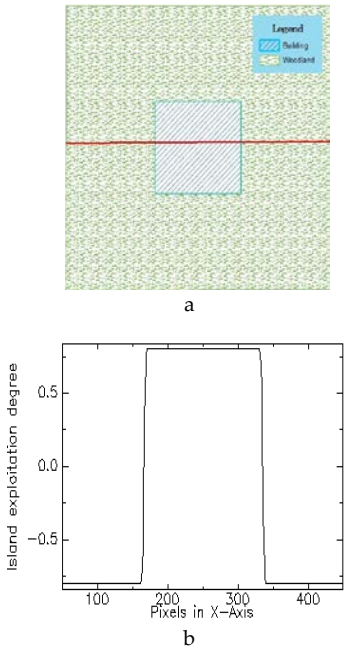


FIG. 1 CONCEPTUAL MODEL OF ISLAND EXPLOITATION

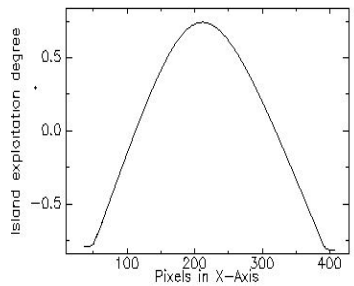


FIG. 2 THE MODEL OF ISLANDS EXPLOITATION DEGREE

Islands exploitation is a slow gradual process, so islands exploitation degree, from man-made buildings to nature environment, is a continuous trend, which means the islands exploitation degree should be a smoother convex curve mostly like figure 2.

The convex curves in FIG.1(b) and FIG.2 can depict exploitation degree of the profile. However, compared to figure 1(b), FIG.2 can not only describe the whole differences in macro-scope, but also the continue changes of island exploitation degree from high to low in details. Therefore FIG.2 is more reasonable than FIG.1(b) to describe the island exploitation degree.

Evaluation model

Human activities are main cause to the change of vegetation (Zhao 2002), so vegetation index can be an indicator to of human exploitation degree.

Based on remote sensing, there are many vegetation indices to depict vegetation information, such as ratio vegetation index, soil adjusted vegetation index, difference vegetation index, NDVI, etc, among which NDVI is more widely used in comparison with others.

NDVI is defined as the ratio between difference and sum of NIR band and red band:

$$NDVI = \frac{DN_{NIR} - DN_R}{DN_{NIR} + DN_R} \quad (1)$$

NDVI reduces effects of errors such as terrain, atmosphere condition, satellite observation angle, and solar elevation angle, and it is a good indicator to vegetation coverage, environment status, and vegetation productivity[11,18].

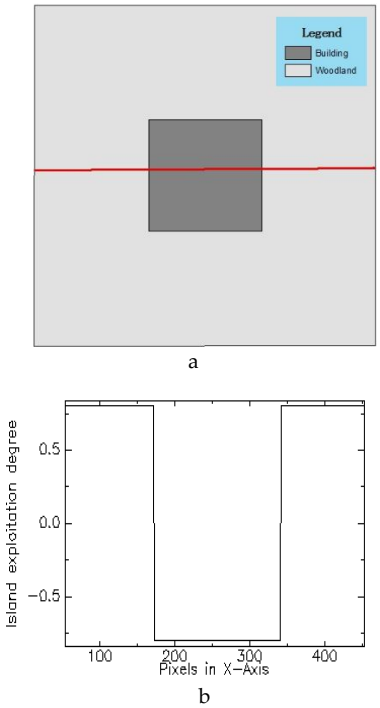


FIG. 3 NDVI IMAGE OF MODEL

As FIG.1(a) shows, in the central of conceptual model, land exploitation degree is the highest, correspondingly, NDVI is the lowest, while -0.8 is assigned to it; for the outside of the model, the exploitation degree is lower, NDVI is higher, if 0.8 is assigned to it, so the co-responding NDVI image of the conceptual model is mostly similar to FIG.3(a). The NDVI value of points on the profile (the red line in FIG.3(a)) from left to right is showed in FIG.3(b).

Compared to FIG.1(b), FIG.3(b) also ignores the continuous trend. That is to say, it is hard to describe the continuous changes of exploitation degree of the profile only by means of NDVI. Thus, a multi-scale analysis method has been proposed based on NDVI and its ecological meanings. The formula of model is as equation (2).

$$V_i = \frac{\sum_{m=0}^{i-1}\sum_{n=0}^{i-1} P_{(m,n)}}{i*i} (i = 1,3,5,7\cdots M) \quad (2)$$

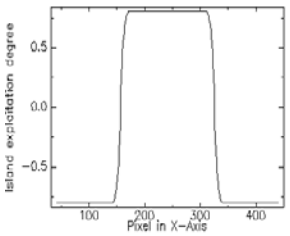
In equation(2), M expresses the window size in pixel, V_i expresses the average NDVI value of central pixel under each window size, m stands for the number of rows, n is the number of columns, and $P_{(m,n)}$ is the pixel value.

Considering NDVI vegetation index has a negative relationship with human activities, island exploitation degree L of central pixel is defined as:

$$L = (-1) * \frac{\sum_{j=1}^{NUM} V_j}{NUM} \quad (3)$$

NUM determined by range of influence of external factors expresses the number of scales, $P_{(m,n)}$ ranges from -1 to 1. Similarly, island exploitation degree L ranges from -1 to 1, and the larger L is , the higher the island exploitation degree is.

Taking NDVI image of model (FIG.3(a)) as data source, the profiles of exploitation degree of the profile (the red line in the FIG.3(a)) under serial scales are plotted using formula (2) and formula (3) in FIG.4. In comparison with FIG.3(b), FIG.4 can reasonably and continuously describe island exploitation degree both in macro-scope and microscope, that is, with the increment of the window size, the curves get more close to the ideal curve in FIG. 2.



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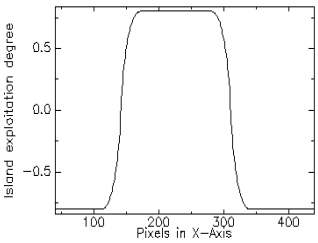

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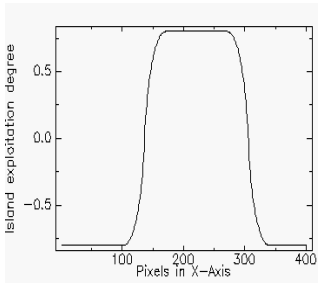

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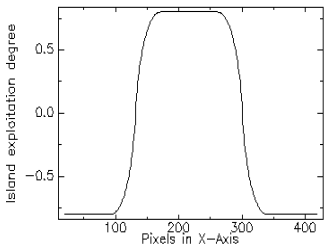

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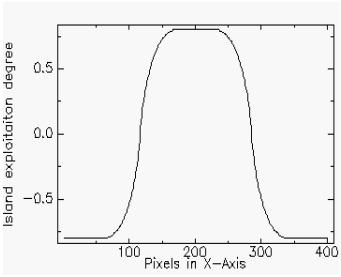

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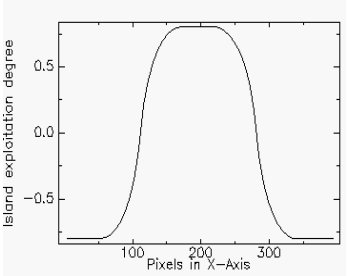


F

FIG. 4(a) moving window with 30 pixels size,
(b) moving window with 50 pixels size,
(c) moving window with 70 pixels size,
(d)moving window with 90 pixels size,
(e) moving window with 110 pixels size,
(f) moving window with 120 pixels size

Experiment

Study area

The study area of the experiment is Daxie Island,

which is located in Beilun District, Ninbo City, Zhejiang Province, with a total area approximately 30.84 km², more than 50% of which is hill. It also has 10.7 km deepwater shoreline, and takes advantage in the building of large ports. Daxie Island exploitation degree has been improved year by year, and now it has formed three industrial patterns including energy transportation, port logistics, and port oil chemical.

Data source

The remote sensing image, used in the experiment is SPOT-5 merged multispectral image (FIG.5) with 5 m spatial resolution, obtained in September 7, 2003. The original image has a high quality, without cloud coverage. The image has four bands including visible green band, visible red band, near-infrared band and shortwave near-infrared band. By means of formula (1), the derived NDVI is illustrated in FIG.6.

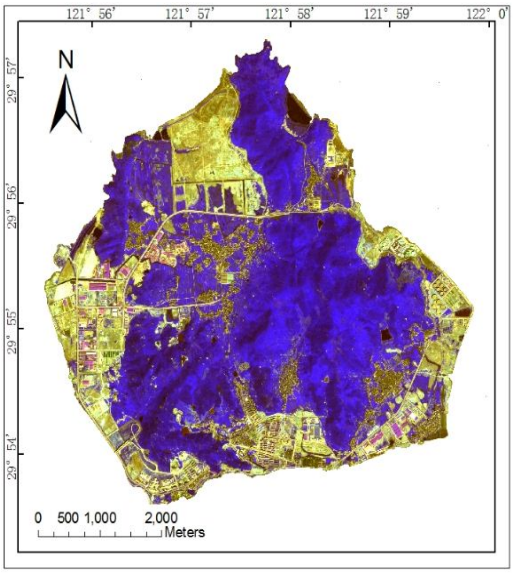


FIG.5 SPOT-5 IMAGE OF DAXIE ISLAND

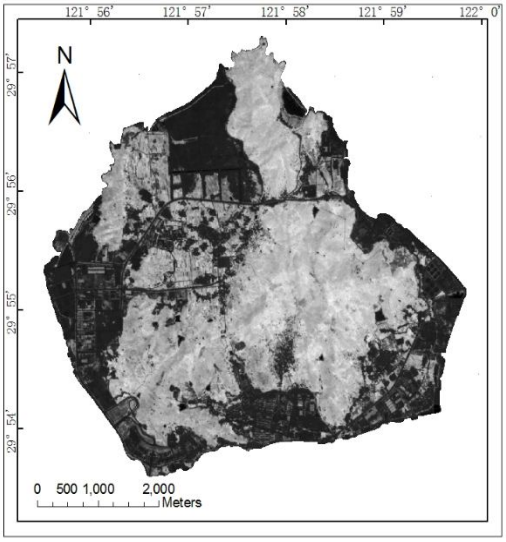
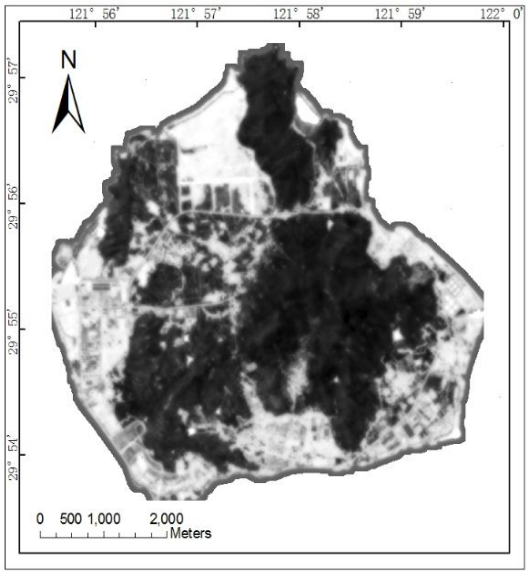


FIG.6 NDVI IMAGE OF DAXIE ISLAND

Result

Using the proposed model, exploitation degree of Daxie Island is calculated (FIG.7(a)). Exploitation degree is divided into four grades from low to high: Extremely high exploitation degree (EHED), High exploitation degree (HED), Median exploitation degree (MED), Low exploitation degree (LED). FIG.7(b) and FIG.7(c) show the contours and classification of exploitation degree, respectively. TABLE 1 lists the area of each grade of exploitation degree.



a

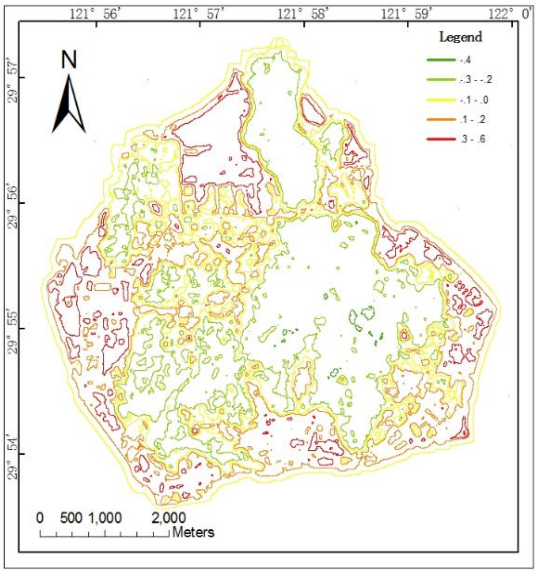


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TABLE 1 AREA OF EVERYGRADE OF EXPLOITATION DEGREE

Region	Degree	Area (m²)	Percentage
EHED	0.2 ~ 0.6	6,578,460	21%
HED	0.1 ~ 0.2	4,385,640	14%
MED	-0.2 ~ 0.1	10,024,320	32%
LED	-0.4 ~ -0.2	10,337,580	33%

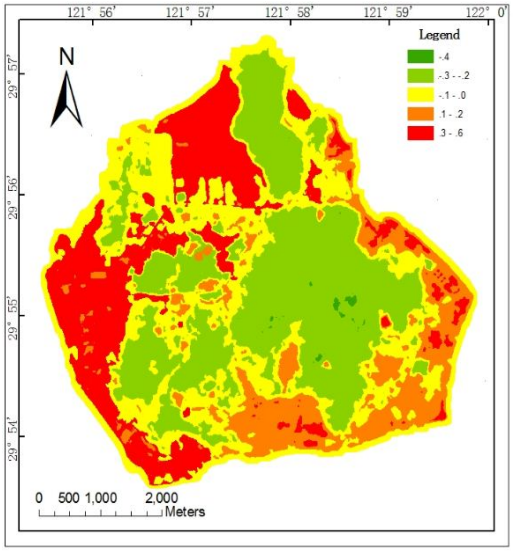

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FIG. 7 EXPLOITATION DEGREE OF DAXIE ISLAND

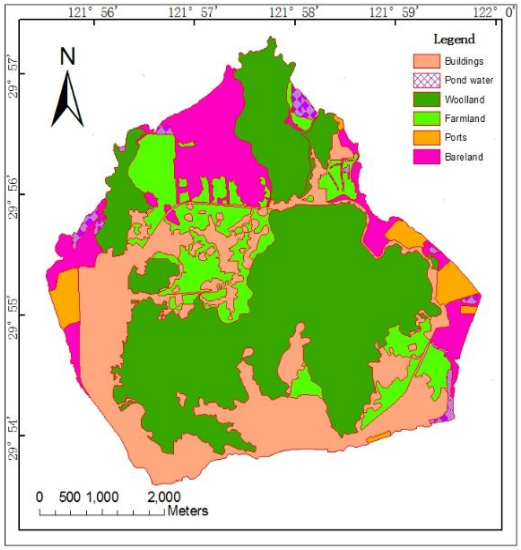

FIG. 8 LAND USE CLASSIFICATION

Based on table 1, the EHED regions(range from 0.2 to 0.6) take about 21% of total area. The regions mainly distributed in northern and western plain of Daxie Island (FIG.7(c)) are alongshore, close to the mainland, and have a convenient transportation and traffic, and have the highest turnover of staff. While the HED regions (range from 0.1 to 0.2) accounting for 14% of total area and mainly distributed in northern and south-eastern of Daxie Island (FIG.7(c)), have convenient transportation as well as much potentials to be developed into extremely high exploitation regions in near future. The MED regions(range from -0.2 to 0.1) occupy about 32% of total area, which are mainly distributed in the intersections of hill and plain. The other LED regions occupy largest percentage of total area, which are mainly distributed in hills of Daxie Island central part. According to the above analysis, the plain regions with convenient transportation and traffic have higher exploitation degree than the hills regions with heavy traffic, which means that traffic and geographical conditions are the main decisive factors in exploiting process.

In order to analyze the proposed method, the land use classification information (FIG.8) is obtained from the same period remote sensing images. By comparison between the island exploitation degree and land use, the EHED regions have the longest history of exploitation than other regions, which mainly contain large scale ports, buildings and ancillary facilities with high density, and part of bare land under construction. The HED regions mainly contain smaller scale ports and buildings, some small scale bare land scattered in internal, which have potentials to be developed into EHED regions in near future. The MED regions mainly contain large scale farmland and aquaculture ponds close to shore. The rest LED regions mainly contain large scale woodland distributed in central of the island.

According to the above comparative analysis between island exploitation degree and land use, the proposed evaluation model based on multi-scale vegetation indices can objectively describe the exploitation status of island. That is to say, the proposed method is reasonable and feasible.

Conclusions

Based on ecological meanings of vegetation index and vegetation's sharp sensitivity to human activities, this paper proposes NDVI multi-scale analysis model, and Daxie Island exploitation degree is evaluated by using the proposed model. The results show that the proposed model is reasonable and effective. Compared to traditional evaluation methods, the new proposed model excludes any economic, demographic and other social statistics, only with need of NDVI. Thus the new proposed model can deal with the divergence of the selection of indices and reduce the difficulties of selection of indices, as well as be applied to large scale island dynamic exploitation evaluation. While there is still some work to be further researched to improve the proposed model, such as how to choose and set reasonable window size in calculation; and how to minimize the seasonal effect in comparison both in the same island or different islands.

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